U.S. Department of Energy
Energy Efficiency and Renewable Energy

The Biomass Program

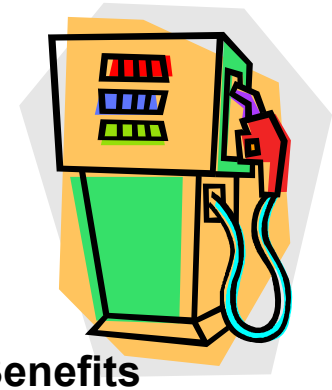
Office of the Biomass Program

Energy Efficiency and Renewable Energy

Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2001*
*Net fossil-fuel electrical imports
**Includes 0.2 quads of imported hydro
***Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

August 2003
Lawrence Livermore
National Laboratory
http://eed.llnl.gov/flow

EERE Biofuels Initiative



What can be done and When?

- 3.4 Billion from corn now will Increase to 12.8-17.8 Billion by 2015
- 30% of our current gasoline use met with biofuels by 2030

The Market Exist

- 25 States have some MTBE Ban
- 4.5+ Million FFV on the road
- 7.5 BGY by 2012 Epact 2005
- 139.6 BGY Gasoline and 37.1 BGY On-Highway Diesel

Environment Benefits

Reformulated gasoline vs. ethanol (E85)

- 18% to 72% less GHG
- 32% to 81% less carbon dioxide (CO_2)
- Up to 58% less methane (CH_4)

National Benefit

The Biofuels Initiative, together with the fuels use reduction and future hydrogen fuels production projected from the Vehicles and Hydrogen programs within EERE, provides a strong energy security portfolio

Strong Support

- Bipartisan Support
- Legislation set up high level Interagency collaboration
- Incentives at State and Federal level
- Strong Industry Support and Interest

Rural Economy

In 2004, the ethanol industry:

- Supported the creation of more than 147,000 jobs
- Boosted U.S. household income by $4.4 billion
- Added $1.3 billion and $1.2 billion of tax revenue for Federal and State/Local governments, respectively

Infrastructure

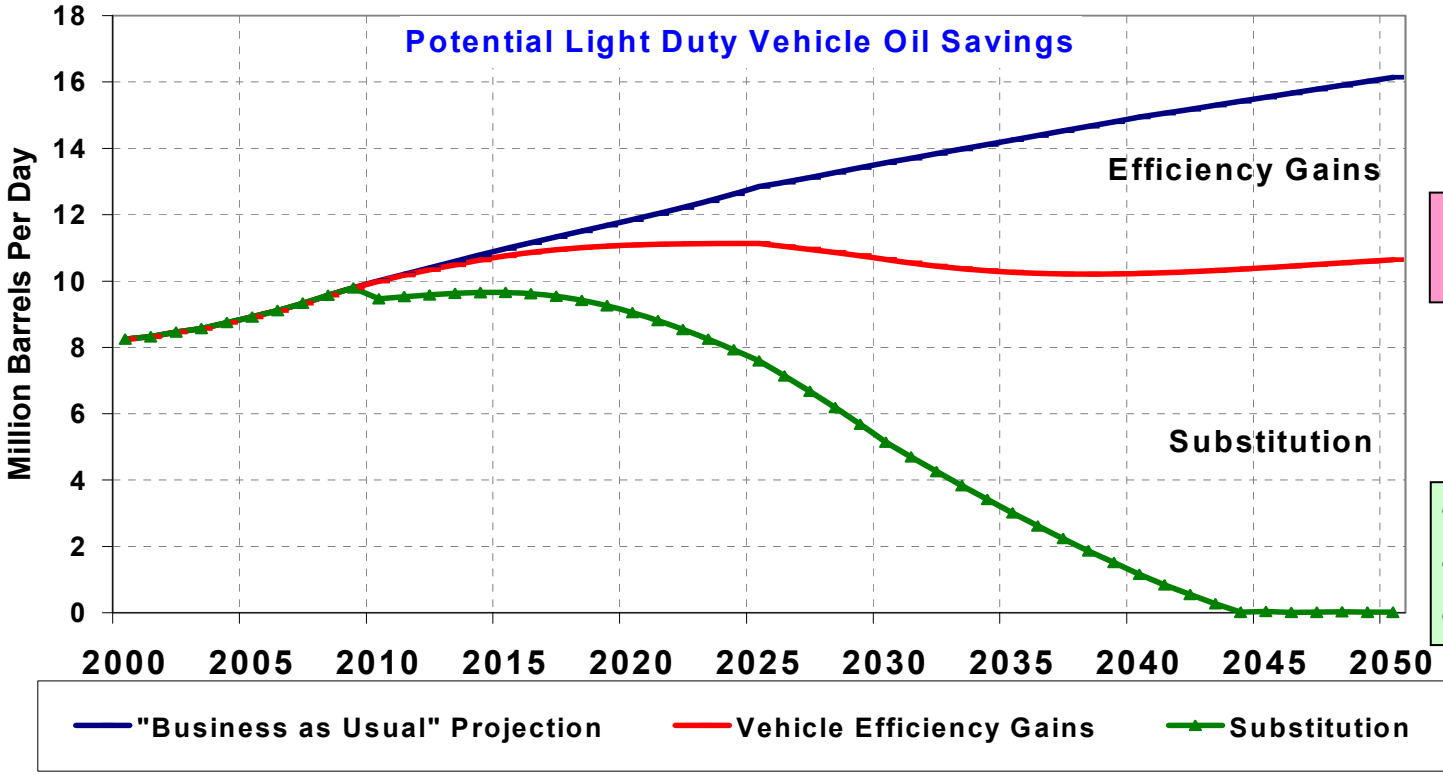
FFV's on the road today and available at dealers

Presently used by blenders and sold in stations

Biofuels: Best Choice Today

- Biomass is the only renewable fuel available that can displace liquid transportation fuels.
- Ethanol and Biodiesel production and markets exist now.
- The use of biomass to produce hydrogen or hydrogen carriers provides long-term value to a diverse future energy supply.
- Collectively, the production of biofuels, improvements in vehicle technologies, and the future hydrogen economy form a strong energy security portfolio.

Removing Light Duty Vehicles from the Oil Demand Equation through Technology Innovation



- Petroleum-based HEVs
- Lighter weight vehicles

- Ethanol-Blends ICEVs/HEVs
- Plug-In HEVs
- H2 FCV HEVs

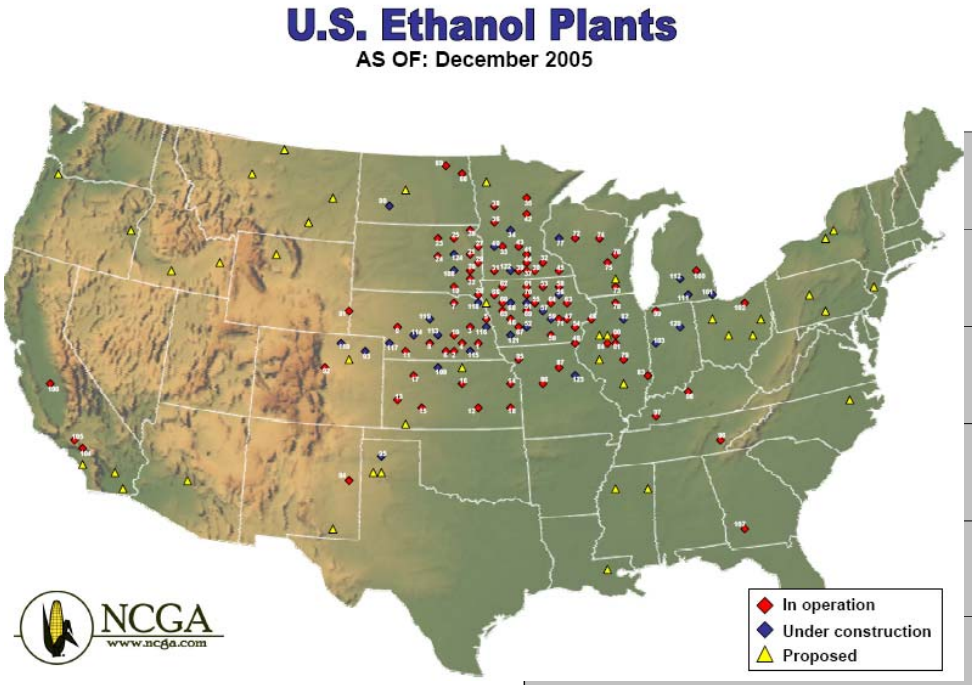
- DOE Role: Balanced Research Portfolio to Overcome Technical and Economic Barriers

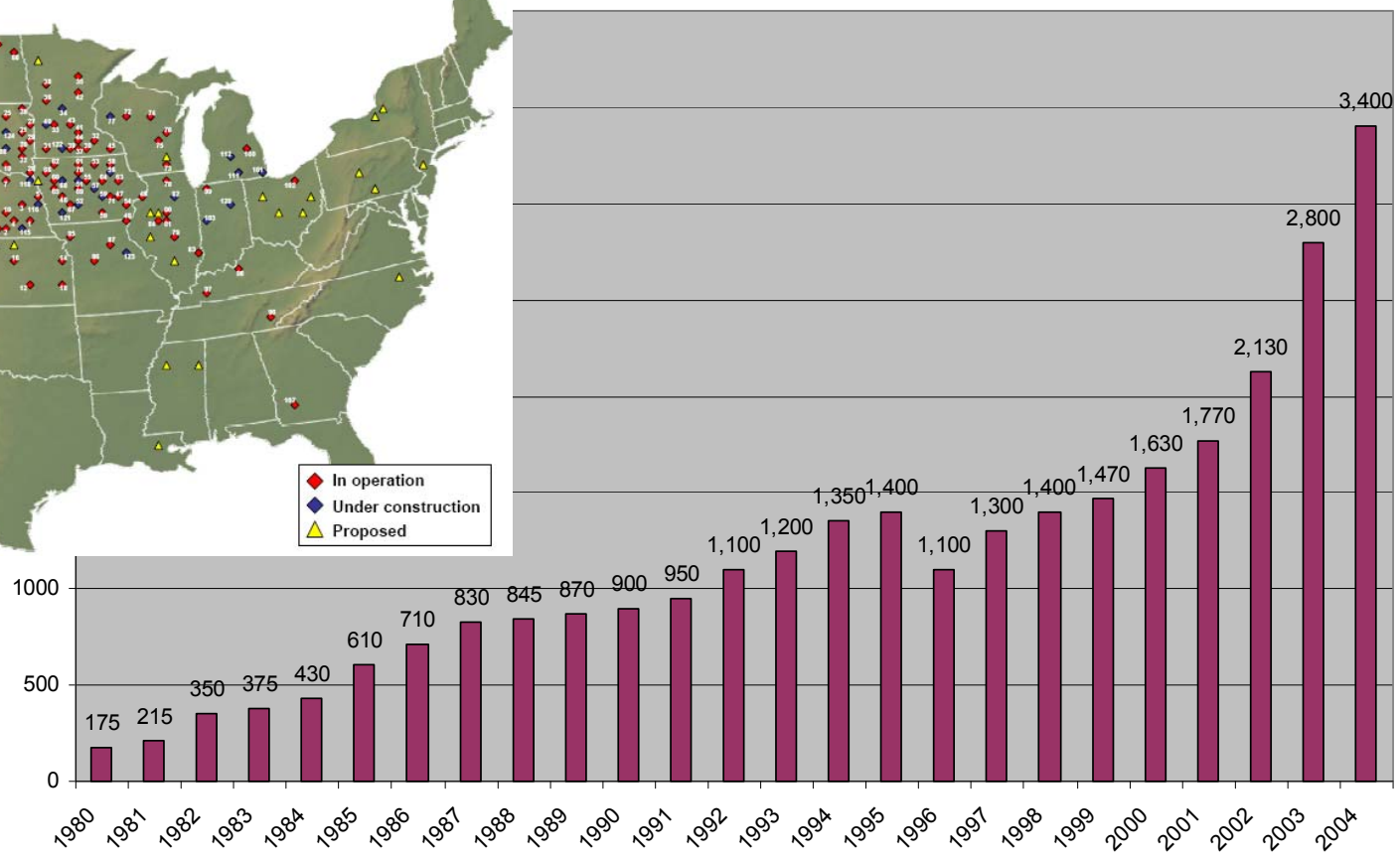
Petroleum-based HEVs	***Lighter Weight Vehicles***	***Ethanol-based ICEVs/HEVS***	***Plug-In Hybrids***	***H2 FCV ICEV/HEVs***
• Hybrid component cost	• Crash worthiness	• Cellulosic feedstock cost	• High energy batteries • Hybrid component cost	• Fuel cell cost • Hydrogen fuel cost • Hydrogen storage

- Markets will determine technology choice(s)

Legend
ICEV: Internal Combustion Engine Vehicle
HEV: Hybrid Electric Vehicle
FCV: Fuel Cell Vehicle

Ethanol Production From Starch

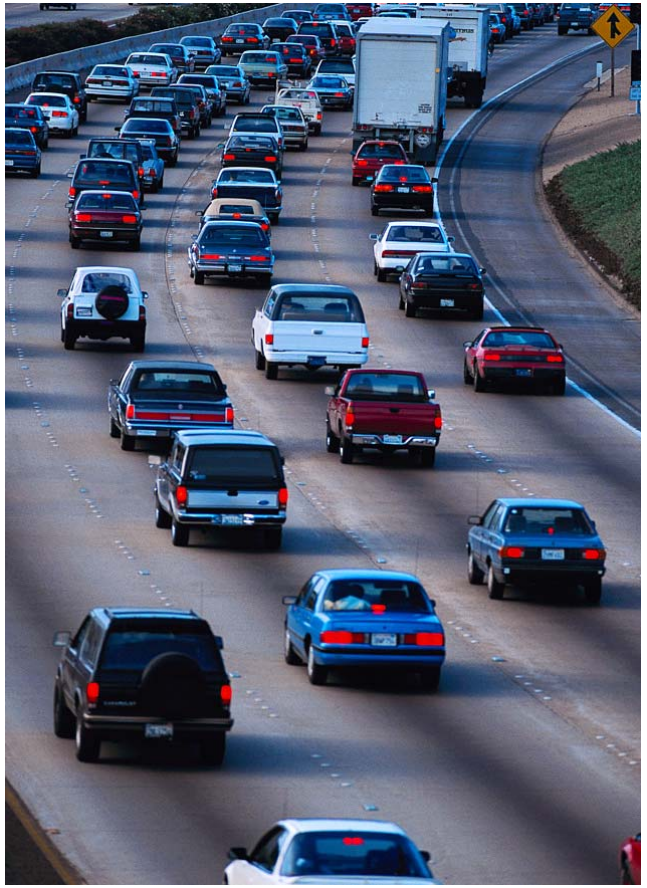




http://www.ethanolrfa.org/industry/statistics/#A

National and Economic Security Benefits

- Biofuels could meet up to 30 percent of our present fuel needs
- Biofuels produced from domestic resources will reduce our dependence on foreign sources of energy
- Energy supply diversity makes us less vulnerable to geopolitical uncertainties, price volatilities, and supply disruptions



Rural Development

- **In 2004, the ethanol industry[1]:**
  - Supported creation of more than 147,000 jobs in all economic sectors
  - Boosted U.S. household income by $4.4 billion through increased economic activity and new jobs
  - Added $1.3 billion and $1.2 billion of tax revenue for federal and state/local governments, respectively
- **A 40 million gallon per year dry mill ethanol plant can[1]:**
  - Expand the local economic base by $110 million annually
  - Create approximately 41 new jobs at the plant
  - Add nearly $20 million to annual household income in the surrounding community
  - Contribute approximately $1.2 million annually to state and local tax revenue
- According to the USDA, ethanol production increases the price a farmer receives for corn by 25-50 cents per bushel

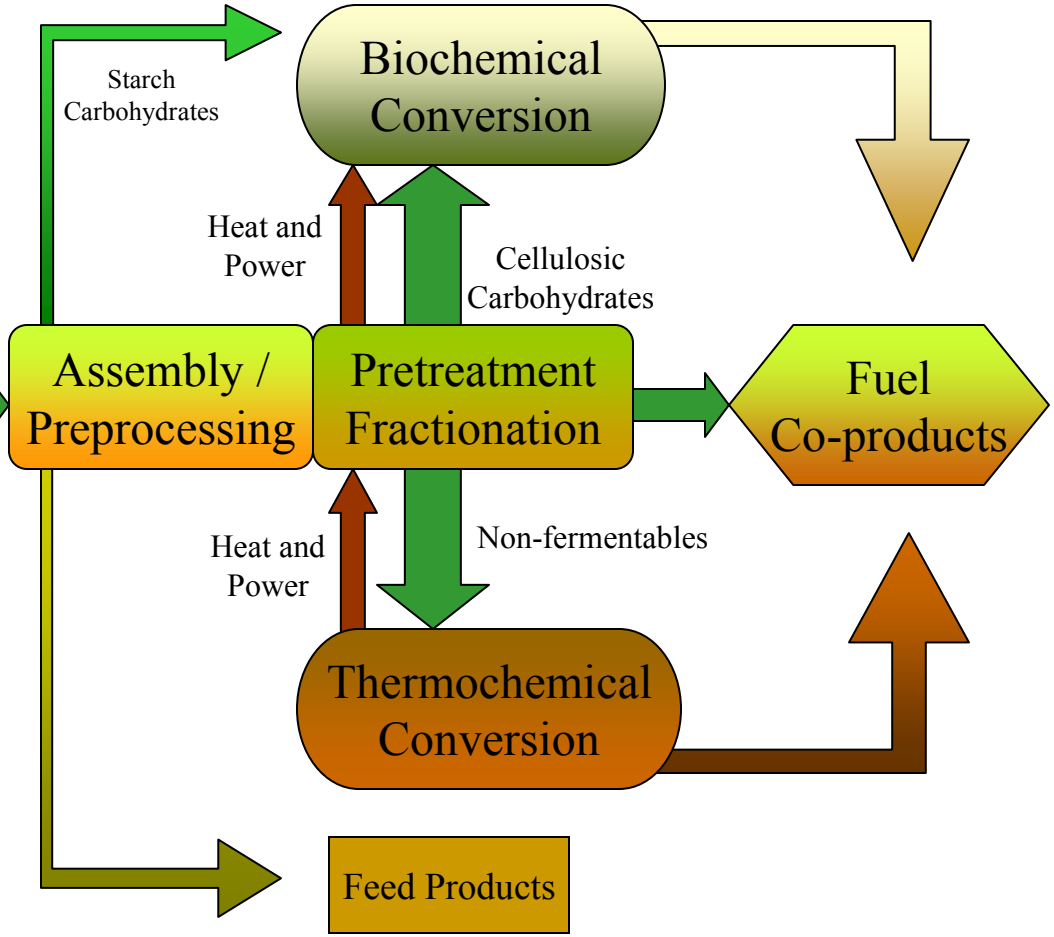
[1] Estimated by applying RIMS II multipliers (U.S. Department of Commerce, Bureau of Economic Analysis) to plant expenditures.

How Do We Get There?

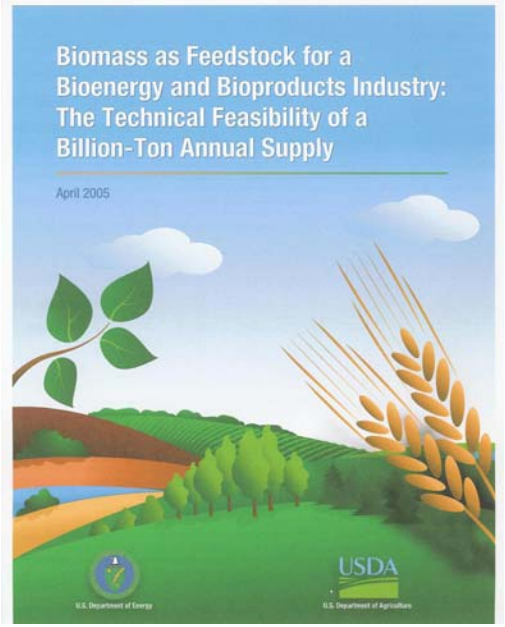
- Provide the fundamental R&D and capability needed for future developments
- Use public policy directives and incentives to drive development and markets
- Implement strategy during 2007 – 2012
  - Help industry build the first unit
  - Cost share industrial-scale validation of multiple pathways to the integrated biorefinery
  - Expand feedstock development efforts

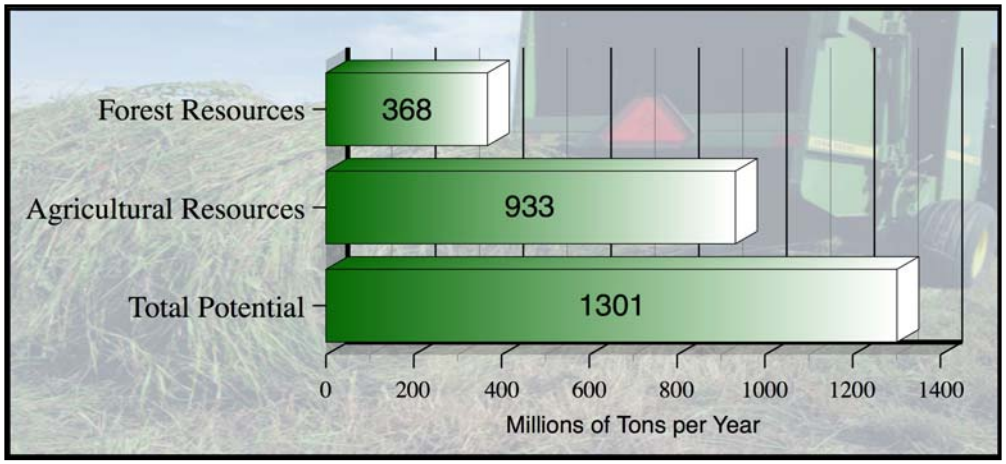
Whole Crop Integrated Biorefinery

The Hub of the Integrated Biorefinery is Feedstock Assembly/Preprocessing, and Pretreatment



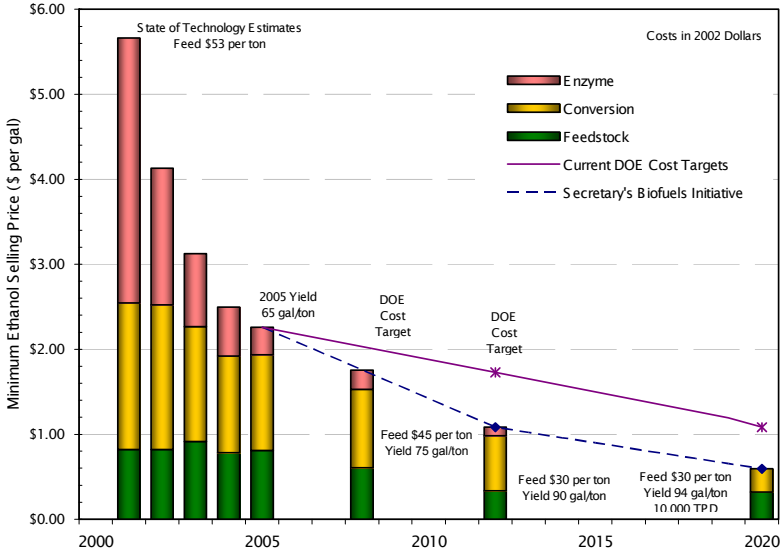
Conversion of Available Feedstocks





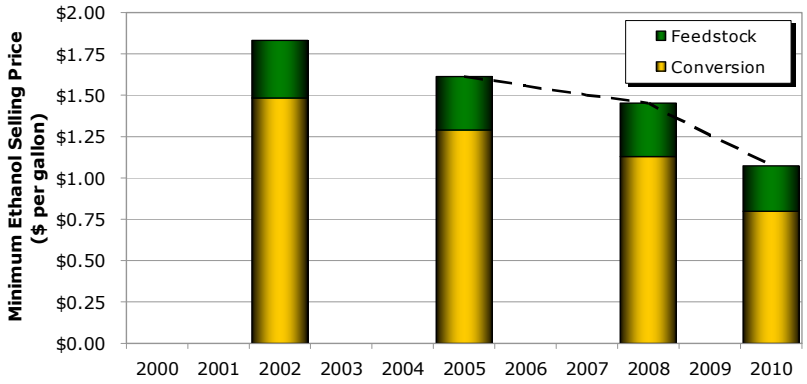
- "Billion Ton" study indicates that enough biomass is potentially available to displace > 30% of current U.S. petroleum consumption
- But it requires variety of biomass types
  - Agricultural lands
    - Corn stover, wheat straw, soybean residue, manure, switchgrass, poplar/willow energy crops, etc.
  - Forest lands
    - Forest thinnings, fuelwoods, logging residues, wood processing and paper mill residues, urban wood wastes, etc.

Fermentation Technology Platform



	2001 Early Enzyme Subcontract	2005 Post Enzyme Subcontract	2010	2012 Market Target
Minimum Ethanol Selling Price	$5.66	$2.26		$1.07
Installed Capital per Annual Gallon		$3.04		1.85
Yield (Gallon/dry ton)		65		90
Feedstock				
Feedstock Cost ($/dry ton)	$53	$53		*$30/35
Pretreatment				
Solids Loading (wt%)	19%	30%	30%	30%
Xylan to Xylose	68%	63%	81%	90%
Xylan to Degradation Products	16%	13%	8%	5%
Conditioning				
Xylose Sugar Loss	13%	13%	4%	0%
Glucose Sugar Loss	12%	12%	4%	0%
Enzymes				
**Enzyme Contribution ($/gal EtOH)	$3.11	$0.32	$0.16	$0.10
Saccharification & Fermentation				
Total Solids Loading (wt%)	13%	20%	20%	20%
Combined Saccharification & Fermentation Time (d)	10	7	5	3
Overall Cellulose to Ethanol	86%	86%	86%	86%
Xylose to Ethanol	76%	76%	80%	85%
Minor Sugars to Ethanol	0%	0%	80%	85%
*$35 per dry ton loose feedstock is equivalent to $30 per dry ton baled feedstock				
**Model value, slightly lower than metric value				

Gasification Technology Platform



	2002	2005	2008	2010 (FY06 Budget Target)
Process Description	Tar Removal & Disposal	Sequential Tar & Light Hydrocarbon Reforming	Sequential Tar & Light Hydrocarbon Reforming — Increased Hydrocarbon Conversion	Consolidated Tar & Light Hydrocarbon Reforming
Minimum Ethanol Selling Price ($/gal ethanol)	$1.83	$1.61	$1.45	$1.07
Higher Alcohol Co-Product Value (% market value)	85%	85%	85%	85%
Installed capital cost ($/annual gal MA)	$3.01	$2.71	$2.69	$2.36
Operating cost ($/annual gal MA)	$0.87	$0.81	$0.75	$0.50
Ethanol Yield (gal/dry ton)	55	56	56	55
Mixed Alcohol Yield (gal/dry ton)	75	77	77	76
Feedstock				
Feedstock Type	Woods Chips	Woods Chips	Biorefinery residues	Biorefinery residues
Feedstock cost ($/dry ton)	$30	$30	$30	$30
Thermochemical conversion				
Process type	Low Pressure Indirect Gasification	Low Pressure Indirect Gasification	Low Pressure Indirect Gasification	Low Pressure Indirect Gasification
Syngas yield (lb/lb dry feed)	0.78	0.78	0.78	0.78
Benzene & Tar yield (lb/lb dry feed)	0.014	0.014	0.014	0.014
Raw syngas methane (mol% - dry basis)	15.36	15.36	15.36	15.36
Cleanup and Conditioning				
Methane out of tar reformer (mol% - dry basis)	N/A	8.25	4.6	1.73
Tar reformer performance:				
Light HC reforming - % CH4 conversion	N/A	20%	50%	80%
Heavy HC reforming - % benzene	N/A	70%	90%	99%
Heavy HC reforming - %tar conversion	N/A	95%	97%	99.9%
Light HC reforming - % CH4 conversion	79%	79%	79%	NA
Sulfur removal	1 ppmv (SMR)	1 ppmv (SMR)	1 ppmv (SMR)	50 ppmv (MA)
H2/CO ratio for fuel synthesis	1.2	1.2	1.2	1.2
CO2 recycle (lb/lb dry feed)	1.99	1.72	1.69	0.51
Compression for fuel synthesis (psia)	2,000	2,000	2,000	2,000
Catalytic Fuel Synthesis				
Single pass CO conversion	38.5	38.5	38.5	38.5
Overall CO conversion	96.9	96.9	96.9	96.9
CO selectivity to alcohols	80	80	80	80

Biofuels Summary & Conclusions

- ✓ The only domestic & renewable option for liquid transportation fuels.
- ✓ Resource base sufficient to supply a large fraction of U.S. needs
- ✓ The “net” energy balance is very good.
- ✓ A sustainable solution to meet the near-term “gap” caused by Peak Oil
- ✓ Science & Technology will create many other opportunities that extend beyond today’s ethanol & biodiesel

Data Sources and Notes for "Biofuels Production Initiative"

- **Existing Fuels Market**
  - 139.6 billion gallons of finished motor gasoline in 2004: EIA Petroleum Supply Annual 2004, Volume 1, Table 3. U.S. Daily Average Supply and Disposition of Crude Oil and Petroleum Products, 2004, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/current/pdf/table_03.pdf
  - 37.1 billion gallons of on-highway diesel in 2004: EIA Fuel Oil and Kerosene Sales 2004, Table 13. Adjusted Sales of Distillate Fuel Oil by Energy Use in the United States: 2000-2004, http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/fuel_oil_and_kerosene_sales/historical/2004/pdf/table13.pdf
  - Energy Policy Act of 2005, H.R.6, Sec. 1501 Renewable Content of Gasoline: "any gasoline sold or introduced to commerce in the U.S. must contain, on an annual average basis, the applicable volume of renewable fuel." applicable volume is 4 billion gallon per year in 2006 and increases steadily to 7.5 billion gallon per year in 2012.
  - State MTBE ban information from *Ethanol Industry Outlook 2005*, Renewable Fuels Association, http://www.ethanolrfa.org/industry/outlook/
  - 2002 MTBE Demand: *Transportation Energy Data Book, Edition 24,* Oak Ridge National Laboratory, Center for Transportation Analysis, 2004. ~93,500 Btu/gal MTBE.
  - MTBE-Ethanol equivalent: conversion from *Ability of the U.S. Ethanol Industry to Replace MTBE*, AUS Consultants, March 2000, retrieved from http://www.ethanolrfa.org/resources/reports/
  - # of FFV (as of the end of production of model year 2005): National Ethanol Vehicle Coalition, "Frequently Asked Questions," Accessed Jan 17 2006, http://www.e85fuels.com/e85101/faq.php. Fuel consumption is estimated using the ratio of 1.9 million FFV to 1.5 B gal/yr ethanol. Ratio is from "Legislative Information Alert: E85 Infrastructure Development," National Ethanol Vehicle Coalition, Accessed Dec 27 2005, http://www.e85fuel.com/pdf/infrastructure.pdf and from "For Your Information," National Ethanol Vehicle Coalition, July 27 2001, http://www.e85fuel.com/news/072701.htm. Note that the much of the 1.5 million FFVs on the road use gasoline and not E85. Approximately 100,000 FFVs (Federal and State government, and fuel provider fleets vehicles only) ran on E85 in 2004 (EIA, DOE, Alternatives to Traditional Transportation Fuels, Table 21. Number of Onroad Alternative Fuel Vehicles in Use by User, Weight Class, Fuel Type and Configuration, 2004, October 2005, http://www.eia.doe.gov/cneaf/alternate/page/atftables/atf21-35_04.html)

Data Sources and Notes for "Biofuels Production Initiative"

- **Ethanol Production**
  - 3.4 billion gallons of fuel ethanol production in 2004: Renewable Fuels Association "Historic U.S. Fuel Ethanol Production," http://www.ethanolrfa.org/industry/statistics
  - 4.3 billion gallons existing capacity in 2004 and an additional 1.8 billion gallon capacity from construction and expansions totaling 6.1 billion gallons ethanol production capacity: Renewable Fuels Association Plant Locations, "U.S. Fuel Ethanol Industry Plants and Production Capacity," http://www.ethanolrfa.org/industry/locations/
  - Between 12.8 and 17.8 billion gallons of fuel ethanol from corn in 10 years is reasonable.: Analysis by NCGA in December 2005, "NCGA Corn-to-ethanol Capacity estimates for 10% fuel ethanol inclusion nationwide by 2015"
    - Analysis includes increased corn yield per acre (from 148.4 to 178-187 bu/acre), acreage (from 74.3 million acres to 76-78 million acres due to ability to grow corn on corn due to biotechnology and crop management programs), and ethanol yield (2.73 gal/bu to 2.9-3.0 gal/bu due to greater number of dry mills).
    - Does not take into account emerging ethanol production technologies.
  - Low heating valued for Ethanol (75,700 Btu/gallon) and Gasoline (115,000 Btu/gallon): Bioenergy Conversion Factors: http://bioenergy.ornl.gov/papers/misc/energy_conv.html

Data Sources and Notes for "Biofuels Production Initiative"

- **Environmental Benefits**
  - E85 emissions are from Appendix D in Brinkman, N., Wang, M., Weber, T., Darlington, T., *Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems—A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions,* May 2005, http://www.transportation.anl.gov/software/GREET/publications.html.
    - Cellulosic ethanol production analysis includes electricity export.
    - Emissions reductions were calculated using the P90 (90% probability that actual values would be equal to or below the P90 values) values.
    - Ethanol has higher NOx, VOC, and PM emissions than gasoline due to farming operations (fossil fuel consumption, use of nitrogen fertilizers, nitrification and denitrification in corn fields) and ethanol production (use of coal or natural gas to produce steam in ethanol mills) (pages 5, 7). (NOx is a GHG; VOCs contribute to GHGs when they react/degrade in the atmosphere).
  - Biodiesel emissions are from Figure IV.A.1-1 Basic Emission Correlations in *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions, Draft Technical Report,* U.S. Environmental Protection Agency, Office of Transportation and Air Quality, EPA420-P-02-001, October 2002. Emissions are calculated for heavy-duty highway engines.

Data Sources and Notes for "Biofuels Production Initiative"

- **Rural Development**
  - 2004 Rural Development numbers are from Urbanchuk, J.M., "Contribution of the Ethanol Industry to the Economy of the United States," LECG LLC, January 2005, http://www.ethanolrfa.org/resource/reports/
    - Applies the detailed industry RIMS II multipliers (Bureau of Economic Analysis, U.S. Department of Commerce) to estimates of spending by the ethanol industry.
  - 40 million gallon mill rural development numbers are from Urbanchuk, J.M., and Kapell, J., "Ethanol and the Local Community," AUS Consultants and SJH & Company, June 2002, retrieved from http://www.ethanolrfa.org/resource/reports/
    - Applies final demand, two-digit industry RIMS II multipliers from the Bureau of Economic Analysis, U.S. Department of Commerce to the estimates of new capital spending and annual operating expenditures of a 40 million gallon dry ethanol plant.